Reprinted from Wildlife Society Bulletin
Volume 28, Number 3, Fall 2000

Efficacy of guard llamas to reduce canine predation on domestic sheep

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Abstract Coyotes (*Canis latrans*) can pose serious economic threats to sheep producers throughout the western United States. At the same time, important segments of the public prefer environmentally benign means to resolve conflicts with wild species. We evaluated the effectiveness of guard llamas to reduce canine predation on domestic sheep by placing 20 llamas with Utah sheep producers and comparing data collected from these flocks over 20 months with similar data collected from flocks without llamas. Comparisons included proportion of flocks with losses to predators and mean predation rates on ewes and lambs. We also conducted surveys to assess producer opinions about including llamas in their sheep management programs. In all comparisons of lamb losses between treatments and controls, losses sustained by control flocks in the first summer grazing season (SGS1) were significantly greater than in flocks with llamas. Among treatment flocks, losses were similar for SGS1 and the second summer grazing season (SGS2). Among controls, losses were greater in SGS1 and dropped to levels similar to treatment flocks in SGS2. The results suggest that predation may have to reach a threshold before guard llamas have noticeable effects on losses. Surveys of producers with llamas indicated strong support for using llamas as guard animals for sheep.

Key words *Canis latrans,* coyotes, domestic sheep, guard animals, llamas, predation, predator control, Utah

Predation, especially by canines, is a serious problem for American sheep producers. In 1994, 40% of sheep and lamb losses in the United States were caused by predators, resulting in an estimated loss of $17.7 million to sheep producers (National Agricultural Statistics Service 1995). Coyotes (*Canis latrans*) accounted for 66% of all predator-caused losses reported.

Methods to reduce predation on livestock often rely on removing predators (Coppinger et al. 1983), but there are ethical and ecological concerns about using lethal depredation control techniques. These concerns emphasize the need to develop alternative ways of reducing livestock depredations (Linhart 1981, Coppinger et al. 1983, Green 1990, Green and Woodruff 1996). Using guard animals addresses many of these concerns and has proven effective at reducing livestock losses to predators (Coppinger et al. 1983, Green et al. 1984, Andelt 1992).

Dogs, typically breeds selectively bred in Europe and Asia for large size, attentiveness toward livestock, trustworthiness, and aggressiveness toward predators, are the species used most commonly to guard livestock (Coppinger et al. 1983, Green 1990). Donkeys also have been used as livestock guardians, especially in Texas (Green 1989*a*, Walton and Feild 1989).

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Since the early 1980s, some sheep producers have used llamas, a South American camelid, to protect their flocks (Markham et al. 1993). Llamas exhibit behaviors similar to their wild predecessor, the guanaco (*Lama guanicoe*), and are known to defend territories and family groups (Franklin and Powell 1994). Llamas are considered most effective against canine species such as coyotes, red foxes (*Vulpes vulpes*), and domestic dogs (Markham et al. 1993). Llamas have an inherent dislike for canines and, when pastured away from other llamas, readily bond with sheep (Green 1990, Markham et al. 1993). In addition to aggressive interactions with canines, llamas also may provide passive protection because predators that rely on stealth when approaching a flock of sheep may abandon attacks when detected by an alert llama.

Guard llamas provide some advantages over guard dogs, including 1) greater longevity, 2) fewer training requirements, 3) faster acquisition of guardian status, 4) fewer special management considerations involving food and maintenance, and 5) compatibility with other depredation control techniques. Despite a plethora of anecdotal articles and producer testimonials concerning guard llamas, there is little quantitative information regarding their efficacy as livestock guardians. The few studies reported are based on surveys and rancher interviews, with no controlled studies assessing the efficacy of llamas in reducing predation on livestock.

We evaluated the effectiveness of llamas to reduce canine predation on domestic sheep by comparing data on sheep loss to predators between flocks with llamas and comparable flocks without llamas. We also conducted surveys to assess producer opinions about guard llama effectiveness.

Methods

We contacted sheep producers throughout Utah by telephone during February and March 1996 and asked several questions regarding their sheep husbandry and predator control practices. Interested producers were selected to participate in the study if they had a history of sheep loss to coyotes, grazed their sheep within fenced pastures year-round, and were not already using guard animals. Sheep management practices in this region typically involved periodic separation and combining of flocks to accommodate changing grazing situations and husbandry practices. Consequently, number of flocks, as well as number of sheep within specific flocks, varied throughout the study. Number of "treatment flocks" was determined by the number of llamas, with each llama placed with a separate flock in April 1996. Number of "control flocks" changed in accord with sheep management programs of individual producers and number present during any specific data-reporting period varied between 8 and 29.

During the study, there were 3 changes in llama assignment. One llama, inappropriately placed in a situation without a history of coyote predation, was removed from its original flock in December 1996 and placed with a flock that had been serving as a control. We removed a second llama from the study in May 1997 because it frequently jumped fences and joined other groups of sheep. A third llama died of natural causes in June 1997. We reassigned flocks whose llama was removed or died as control flocks and assumed no residual effect of the llama on subsequent predation patterns.

Data collection

We contacted each sheep producer by telephone every 2 weeks from May 1996 through December 1997 (40 data-reporting periods). Numbers of ewes and lambs that died within each 2-week period were reported and categorized as either predator-caused, natural, accidental, or unknown. If predator kills occurred, we asked the producer the number of ewes or lambs killed and the predator species responsible. We also asked the number of ewes and lambs in the flock; size, cover, and topography of the pasture; and whether any depredation control methods had been used during the previous 2 weeks. Producers with multiple flocks reported information separately for each flock. In addition, we asked producers with llamas about the llamas' behavior and any changes incorporated into their sheep management program because of the llama, as well as the llamas' interaction with the sheep.

During summer and fall, we visited each treatment and control flock ≥3 times to obtain additional information about cover and topography of pastures, flock location with respect to other treatments and controls, and information on llama behavior and their interactions with the sheep.

Comparisons between treatment and control groups

Some comparisons between treatment and control flocks include all 40 data-reporting periods. Because predation on sheep varied throughout the year, as well as between years, we also present results by season. Summer Grazing Season 1 (SGS1)

included data-reporting periods 1 through 13 (May through Oct 1996), Winter Grazing Season (WGS) included periods 14 through 26 (Nov 1996 through Apr 1997), and Summer Grazing Season 2 (SGS2) was defined as periods 27 through 38 (May through Oct 1997). Periods 39 and 40 (Nov and Dec 1997) were not included in seasonal analyses. Summer grazing seasons represent months when most producers had lambs in their flocks and allowed comparisons between data collected in 1996 and 1997.

Proportion of flocks with losses. To evaluate how pervasive canine predation was among treatment and control flocks, we compared the fraction of flocks in each group that experienced loss for each data-reporting period. Because number of flocks varied among and within groups over time, proportions of treatment and control flocks that experienced ewe and lamb loss to canines were compared and depicted graphically.

Predation rates. Although producers frequently rearranged number and composition of their flocks, number of sheep within the study was relatively stable except for the seasonal ebb and flow of lambs. Because 1) the number of flocks varied among and within groups over time and 2) the number of sheep killed during any one predation incident is generally independent of flock size, we chose to compare predation rates as mean number of sheep killed/flock within each reporting period. We did this graphically and statistically as a 2-way factorial in a split-plot design using a log transformation of the data to compare mean number of lambs killed by canine predators in treatment and control flocks for SGS1 and SGS2 (SAS Institute, Incorporated 1985, 1996). Results of these tests should be interpreted conservatively because flocks were not independent across data-reporting periods, data were not distributed normally, and variances were not heterogenous.

Producer surveys. We conducted 2 surveys. The first was conducted at the end of SGS2 (Dec 1997) and asked each treatment producer 10 questions regarding guard llama use and effectiveness in reducing predation on their sheep. The second, conducted approximately one year after the end of SGS2 (Jan 1999), included only the treatment producers who purchased their llamas at the end of SGS2. They were asked 8 of the 10 original survey questions. We used percentages and frequency distributions to describe treatment producer responses to questions regarding use of guard llamas and their effectiveness.

Results

Sheep producers participating in this study managed their sheep in several ways. Most pastured their sheep most of the year away from, but in the same valley as, their home. Other producers lambed at their farms and moved their flocks to mountain pastures during summer. The least number of producers kept their sheep near their homes year-round. Pasture cover and topography ranged from short grass and flat terrain to densely treed and mountainous, with treatment and control producers dispersed fairly evenly among the various pasture types. Producers with llamas maintained their sheep in pastures averaging 83 ha (range=0.5 to 1,200 ha), whereas pasture size for control flocks averaged 77 ha (range=0.5 to 480 ha). Average number of sheep (ewes plus lambs) in treatment flocks was 301 (range=1 to 3,200) and control flocks averaged 333 (range=27 to 1,596). Lamb numbers for treatment and control flocks averaged 113 (range=0 to 850) and 182 (range=0 to 1,064), respectively.

Three hundred twenty sheep were reported lost to predators, with lambs comprising 85% of these losses. Several species were responsible for these losses (numbers in parentheses indicate numbers of sheep in treatment and control flocks, respectively), including black bears (*Ursus americanus,* 0 and 2), mountain lions (*Puma concolor,* 16 and 6), common ravens (*Corvus corax,* 3 and 0), domestic dogs (22 and 10), red foxes (2 and 3), and coyotes (63 and 193). Dog, fox, and coyote predation accounted for 92% of all sheep losses to predators reported during the study.

Most sheep and lambs killed by canine predators occurred in SGS1. Treatment flocks lost 42 sheep to predators in SGS1 and 35 in SGS2, whereas the control group lost 128 sheep in SGS1 and only 32 in SGS2. WGS had the least sheep killed, with treatment and control flocks losing 10 and 8 sheep, respectively. Because lambs comprised most of the sheep losses to predators, seasonal comparisons of number of lambs killed showed the same trends as numbers of sheep killed.

Proportion of flocks with losses

Proportions of treatment and control flocks with ewes killed by canine predators for each data-reporting period were relatively low compared with the proportions with lamb losses (Figure 1). Canine predation on ewes was erratic, with a slight increase in WGS (Figure 1A).

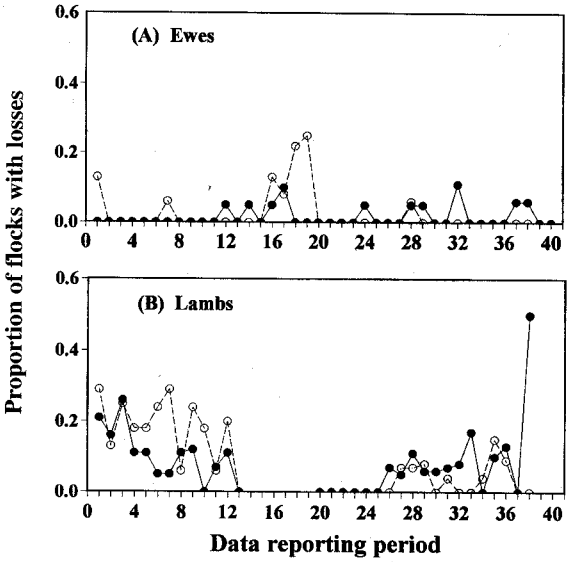

Figure 1. Proportion of treatment (solid) and control (dashed) flocks in Utah with reported losses of ewes (A) and lambs (B) to canine predators during each 2-week data-reporting period, May 1996 through December 1997.

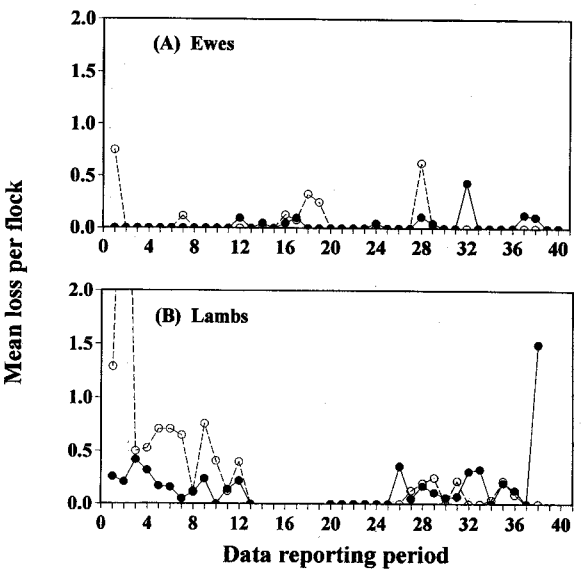

Figure 2. Mean number of ewes (A) and lambs (B) killed by canine predators in treatment (solid) and control (dashed) flocks in Utah during each 2-week data-reporting period, May 1996 through December 1997 (control value for x=2 in graph B is 4.6).

The proportions of flocks with lamb losses were greater and more consistent than ewe losses (Figure 1B). Lamb losses were generally confined to SGS1 and SGS2. Treatment flocks appeared to have similar proportions of flocks with loss during SGS1 and SGS2, whereas the proportions of control flocks with loss were greater in SGS1 and dropped to levels similar to treatment flocks in SGS2.

Predation rates

Mean predation rates of ewes were low and did not appear to differ between treatment and control flocks (Figure 2A). Those of lambs were greater and more consistent than ewe predation rates and provided a better comparison between treatment and control flocks (Figure 2B). Mean lamb predation rates among treatment flocks were significantly less than those of control flocks in SGS1 ($F_{1,41}$=8.02, P =0.007) but not in SGS2 ($F_{1,56}$=0.05, P=0.829). Estimates of variability among flocks were 0.01 and 0.001 for SGS1 and SGS2, respectively; estimates of variability among repeated measures on flocks were 0.33 and 0.11 for SGS1 and SGS2, respectively. All variances were reported in units of [log(mean number of lambs killed)]^2. Treatment flocks appeared to have similar mean lamb predation rates during SGS1 and SGS2, whereas the predation rates of control flocks with losses were greater in SGS1 and dropped to the level of treatment flocks in SGS2.

Producer surveys

Prior to the study, 12 of 20 (60%) producers who received llamas claimed "no opinion" on guard llama effectiveness in reducing predation on

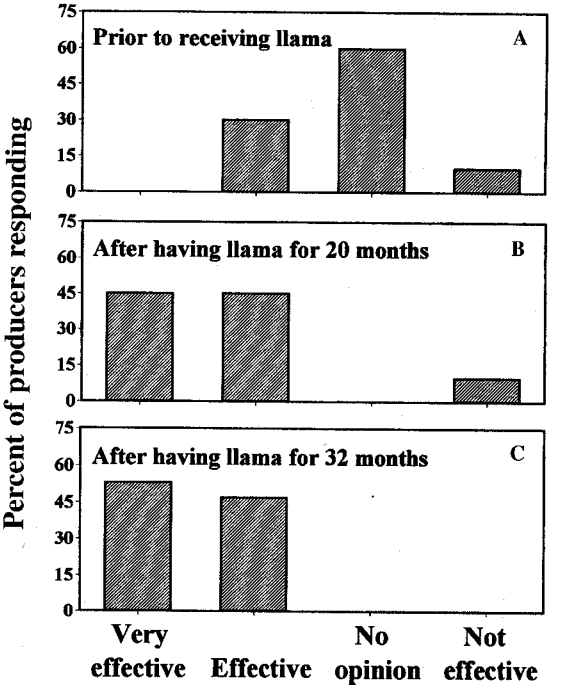

Figure 3. Comparison of opinions of participating producers regarding guard llama effectiveness in reducing predation on domestic sheep in Utah (A) prior to receiving a llama, and after having a llama for (B) 20 months and (C) 32 months.

Table 1. Responses of participating sheep producers in Utah to survey questions related to use and effectiveness of guard llamas in deterring predation on sheep during surveys in 1997 and 1999.

Question	Affirmative responses (%) Survey 1[a] (n=20)	Survey 2[b] (n=15)
Has presence of llama:		
Provided greater peace of mind regarding your sheep?	85	87
Caused you to change normal flock management practices?	30	0
Let you rely less on other depredation control methods?	30	67
Reduced your reliance on predation control specialists?	15	67
Has your llama reduced the number of sheep lost to predators?	100	93
Would you recommend guard llamas to other sheep producers?	100	93

[a] Survey conducted in December 1997 after producers had used llamas for 20 months.
[b] Survey conducted in January 1999 after producers had used llamas for 32 months.

domestic sheep; none of the producers thought a guard llama would be very effective; 6 (30%) felt a guard llama would be effective; and 2 (10%) thought using a guard llama would not be effective (Figure 3A). After having a llama with their sheep for 20 months, 9 of 20 (45%) producers claimed the llamas were very effective at reducing predation on their sheep, 9 (45%) rated their llama as effective, none claimed no opinion, and 2 (10%) felt their llama was not effective (Figure 3B). At the end of SGS2, 17 treatment producers had the option of purchasing their llama. Sixteen (94%) did so for $350 each and one (6%) with 2 llamas decided not to purchase either. When re-contacted one year later, 15 (94%) producers were still using llamas as guard animals and the other had sold his to another sheep producer. Of the 15 still using the llamas, 53% rated them as very effective, 47% as effective, and none claimed no opinion or rated their llamas as not effective (Figure 3C).

Table 2. Producer assessments of the efficacy of llamas and dogs in protecting sheep from canine predation, as reported in 8 surveys.

Species and source of information	Effectiveness category (% of producers) Very effective	Effective	Somewhat effective	Not effective
Guard llamas				
Meadows (1999)[a]	45	35	10	10
Meadows (1999)[b]	54	33	13	0
Powell (1993)	52	28	15	5
USDA (1996)	53	35	11	1
Guard dogs				
Andelt (1992)[c]	57	38	5	na[d]
Green (1989b)[e]	68	17	na	15
Green & Woodruff (1988)[f]	71	21	na	8
USDA (1996)	51	37	11	1

[a] Survey conducted in December 1997 after producers had used llamas for 20 months.
[b] Survey conducted in January 1999 after producers had used llamas for 32 months.
[c] Effectiveness categories reported as "Excellent," "Good," and "Good/poor."
[d] Not applicable
[e] "Somewhat effective" category not included in survey.
[f] Effectiveness categories reported as "Good," "Fair," and "Poor."

In surveys 1 and 2, we asked treatment producers several additional questions regarding guard llama use and effectiveness (Table 1). In both surveys, most producers believed their llamas reduced number of sheep lost to predators and would recommend using guard llamas to other sheep producers. Producers reported they generally did not have to change their sheep management practices to accommodate the llama. In survey 1, only 30% of producers felt they relied less on other depredation control methods and 15% thought they contacted their local WS specialist less often because they had a llama with their sheep; in survey 2, 67% indicated less reliance on other depredation control methods and made fewer calls to their WS specialist.

Fourteen of 20 (70%) producers in survey 1 rated themselves very satisfied with their guard llama, 4 (20%) were satisfied, and 2 (10%) were somewhat satisfied. Producers contacted for survey 2 ($n=15$) responded similarly.

Discussion

We attempted to quantify effectiveness of llamas in preventing canine predation on domestic sheep under typical husbandry practices associated with grazing within fenced pastures in Utah. To enhance accuracy of the data reported, we contacted cooperating sheep producers every 2 weeks and asked about their predation losses, rather than asking them to report on an annual basis. Producers with llamas were encouraged to use them as they thought best suited their respective management programs.

Although environmental circumstances varied among test situations, no important issues were identified in statistical tests for disparities between treatments and controls regarding topography, cover, pasture or flock sizes, or historical patterns of predation.

Overall loss patterns

Number of sheep included in this study declined 13% between 1996 and 1997, representing a reduction in producer inventories rather than a reduction in number of producers. Production information compiled by the Utah Agricultural Statistics Service (1998) indicated a statewide decline of 5% among sheep numbers for the same period.

Initially, the reported losses of sheep (ewes plus lambs) to canine predation (3.8% and 3.3%, respectively in SGS1 and 0.68% and 0.43%, respectively in SGS2) appeared less than the reported sheep loss to predation statewide in 1996 and 1997 (6.6% and 5.8% of respectively, Utah Agricultural Statistics Service 1998). Taylor et al. (1979) reported a 4-year average lamb loss of 5.8% for 10 ranches in southwestern Utah, whereas Gee et al. (1977) reported an average predation loss of 7.7% of lambs in 5 states (Colo., Mont., Nebr., S.D., Tex., and Wyo.) during 1973–1976. This suggests that losses among producers in this study may have been in the lower portion of the typical-loss spectrum.

Potential reasons for the apparent differences in sheep losses include methods of accounting for lambs that are missing but not located (Scrivner et al. 1985). Several authors (Nesse 1974, Guthery and Beason 1977, Wagner 1988) contend that many of the unexplained losses of sheep can be attributed to coyote predation. Stoddart et al. (2001) also inferred that much of the unaccounted loss among lambs may result from predation because no alternate explanation was apparent for the systematic change in loss of lambs that occurred coincident with changing coyote densities. More importantly, Windberg et al. (1997) documented food caching of domestic lamb and kid goat carcasses by coyotes, with some caches more than 1.6 km from where the flocks were grazed. Our producers documented, at 2-week intervals, only numbers of carcasses found, with no accounting for lambs that were "missing." Because we did not get total loss figures from the producers in our study, we could not incorporate adjustments for missing lambs and it remains conjectural whether these producers really were in the lower portion of the loss spectrum.

Initially, the decline (72%) in numbers of lambs killed by canine predators between 1996 and 1997, especially among producers without llamas, lacked explanation. This resulted from a marked decline in the fraction of producers experiencing greater losses. In 1996, over half the flocks in this study reported lamb predation losses >2%, but in 1997 <10% of flocks were in this category (Meadows 1999). This paralleled a statewide trend, with Wildlife Services personnel reporting 18,544 sheep killed by canine predators in FY-96 and only 7,865 in FY-97, a 58% decrease at a time when sheep numbers in Utah declined only 5% (Utah Agricultural Statistics Service 1998). The Utah Agricultural Statistics Service (1998) identified a 12% decline in canine predation-related losses, but its survey included numerous small farm flock operators who typically experience very low predator losses. Thus the decrease in loss rates between 1996 and 1997 reported by study producers appears realistic, although overall losses may be less than for the entire industry within the state.

Losses to canine predators

We used 3 measures to assess the efficacy of llamas in protecting sheep: 1) proportion of flocks incurring loss during each 2-week reporting period, 2) mean loss rate/flock for each reporting period, and 3) producer opinions regarding efficacy of llamas in protecting their sheep. Linkage among assessment parameters is acknowledged.

During the first summer grazing season of the study, both direct assessments of sheep loss provided a strong indication that producers with llamas incurred only about half the canine predation as those without llamas. During the second summer grazing season, predation rates appeared similar between producers with and without llamas, and it is noteworthy that this resulted from losses among control producers declining to levels experienced by producers with llamas, rather than predation rates among producers with llamas rising to levels of the control producers. Had the latter occurred, a suspicion that the llamas had lost effectiveness might seem appropriate. Currently, we can only speculate whether predator densities declined, alternate predator foods increased in availability, efficacy of llamas in protecting sheep changed over time, or there is a threshold below which llamas may be unable to further reduce depredations. Available data does not permit resolution of these alternatives, although at this point we are inclined to believe the last.

While we are cautious about relying solely upon producer opinions to measure the efficacy with which llamas protect sheep, there is little doubt that most producers using guard llamas strongly acknowledge their merits. It is difficult to assess whether these appraisals are associated with inclusion of an exotic creature to their animal inventory; the ease of care and maintenance of llamas; seeing llamas harass and chase dogs, coyotes, or foxes; or actual measures of the protection provided. Regardless, most sheep producers who have used llamas as sheep guards appear very supportive of their use.

Comparisons with other studies

We are aware of only 2 other formal attempts to assess efficacy of llamas in deterring canine predation on sheep, namely that of Powell (1993) and a survey of sheep producers conducted by United States Department of Agriculture's Veterinary Service (United States Department of Agriculture 1996). Both studies relied on producer opinions. The latter indicated that 6% of producers used guard llamas. There was surprising agreement between those studies and ours (Table 2). Among the 4 surveys, 80 to 88% of the respondents considered llamas effective or very effective in deterring predation.

Interestingly, the Veterinary Service survey also inquired about using guard dogs, and of the 38% of producers who claimed to use guard dogs, 88% rated their dogs as moderately or very effective in deterring predation (Table 2). Three additional studies surveyed guard dog owners and asked questions similar to those in this study, including how they would rate their dog's effectiveness in reducing predation on sheep (Green and Woodruff 1988, Green 1989*b*, Andelt 1992). The similarities in producer responses, both among the 3 studies involving llamas and the inquiry to producers using guard dogs, were surprising.

Other considerations

There are benefits and liabilities associated with using llamas as sheep guards compared to using guard dogs. Based on sheep producer assessments, llamas appear to provide depredation protection similar to that provided by dogs. However, llamas require little or no training or socialization period. The animals used in this study were acquired directly from llama producers without special selection or training, except for an 8-month period when they were used on another study (Cavalcanti and Knowlton 1998). Because husbandry practices for llamas are similar to those for sheep, few special management considerations are needed for food, water, or routine veterinary medical care. Llamas pose little threat to humans and are relatively easy to handle, even without training. In addition, llamas may have a guarding tenure in excess of 10 years, whereas that for guarding dogs may average less than 2 years (Green and Woodruff 1983, Lorenz et al. 1986). A less obvious advantage associated with llamas relates to their compatibility with other depredation control procedures. Traps, snares, and M-44s used in depredation control activities can pose serious risks to guard dogs, but cause little concern around llamas. In addition, guard dogs also can interfere with calling and shooting procedures commonly used by depredation control specialists, but llamas usually do not.

A surprising number of reports involving llamas chasing coyotes, foxes, or domestic dogs were received. Additionally, several producers observed llamas "gathering" the sheep and placing themselves between the sheep and an intruding canine.

We are aware of 2 instances among our producers where llamas injured or harassed lambs. In one case a llama inadvertently trampled and killed a newborn lamb; in the other a llama acted aggressively toward a young lamb. In the latter case, the owner discouraged the llama and no further problems were reported. Although others (Markham et al. 1993, Franklin and Powell 1994) report that male llamas sometimes injure or kill adult ewes while attempting to breed with them, we received no such reports, perhaps partially because of our use of gelded male llamas.

Although llamas quickly bond with sheep, most prefer to associate with other llamas if given the opportunity. Several producers reported their llamas jumped out of their pastures when another llama was visible. Moving them to pastures away from the other llamas solved these problems. We eliminated one llama from the study because it repeatedly jumped fences and failed to stay "on assignment."

We are aware of guard llamas being used by some producers under open range, herded sheep management programs, but such circumstances are outside the purview of our study. The degree to which such circumstances complicate the use of llamas or influence their effectiveness remains to be assessed. Similarly, additional information is needed to determine whether specific characteristics of llamas can be associated with the degree of depredation protection provided.

Conclusions

Using llamas to reduce depredations on livestock avoids many of the ethical and ecological objections frequently voiced about lethal depredation control techniques. Our data indicate that guard llamas reduced canine depredation upon lambs during the first year of our study, but not during the second year. We suspect the latter resulted from a general depression of depredations to very low levels throughout our study area and suggest that llamas may be most effective when depredations exceed some lower threshold. Sheep producers experienced in using guard llamas almost universally endorse their use as a depredation deterrent. Producer approvals are comparable to those associated with guard dogs, but many of the management considerations commonly associated with guard dogs do not apply to guard llamas.

Llamas are an option sheep producers can use to deter depredations. Direct assessments of sheep loss and producer opinions suggest that llamas can reduce lamb losses to canine predators. However, guard llamas should be considered part of an integrated depredation control program that includes other nonlethal and lethal depredation control methods when necessary.

Acknowledgments. This study was supported by the National Wildlife Research Center (United States Department of Agriculture, Animal and Plant Health Inspection Service, Wildlife Services) and the Jack H. Berryman Institute at Utah State University and conducted under jurisdiction of the Institutional Animal Care and Use Committees of both institutions (Protocols QA-432 and #736, respectively). We appreciate the introduction to and husbandry advice about llamas provided by D. Markham, the assistance of J. Bowns and M. Conover in developing and executing the study, and statistical counsel offered by S. Durham, as well as the reviews and comments of M. Conover, J. Bowns, R. Mason, W. Pitt, and M. Fall regarding various versions of the manuscript. This study would have been neither practical nor possible without the consistent help from cooperating sheep producers in Utah. Many thanks to all.

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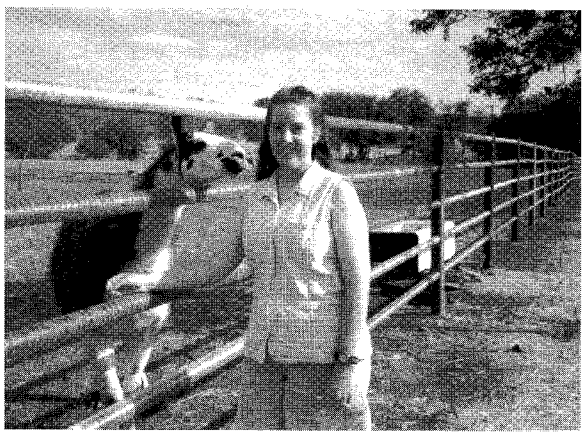

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Associate editor: *Ballard*